Residential Seismic Evaluation Project on Veredas de Yauco, PR

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Abstract

During the earthquake (6.4 magnitude Richter scale) occurred on January 7, 2020 in Puerto Rico, many residential structures on the island were affected. As a result, one of these structures was investigated and analyzed considering the most recent engineering codes and in addition evaluating with the construction deficiencies discovering during the investigation. A structural analysis was performed, considering displacements, moments, steel reinforcements, drift, capacity of vertical/horizontal of structural elements and basal shear. Were identified structural steel design reinforcement deficiencies and serious constructions issues that cause important fails in the structure. After the event, it is recommended to reinforce the structure by performing the construction of new foundations in specific a specific section, rehabilitation of a structural column, changing section from concrete masonry unit (CMU) to one of reinforced concrete and use of carbon applicable fiber reinforcement to increase capacity of certain walls of the structure.

Introduction

The case that will be part of this investigation is a residential structure that suffered considerable structural and physical damage during the 6.4 magnitude seismic in Puerto Rico. All damaged are visual identified as follows: significant cracks in various walls, beams and columns of reinforced concrete; partial demolition of a column; physical separation of block walls on their sides and top against concrete and ceiling walls, respectively; cracks in block walls due to the short column effect; cracks in floor and ceiling; and others architectural damages. Due the magnitude of these damages a structural analysis was performed to confirm if the structure comply with the most recent structural designs codes in Puerto Rico and the reason of the identified fails.

Background

The analyzed structures suffering significant physical damaged that affect its functionality. Consequently the structure was classified non livable and a proper evaluation needs to be perform in order to understand structure respond during the earthquake but the most important the permanent effect after the event. Accordingly, elements collapsed and be affected. After the structural analysis completion, important findings were identified that contribute with the fails of the structure and it's important investigate, if the structure can be usable, livable and savable.

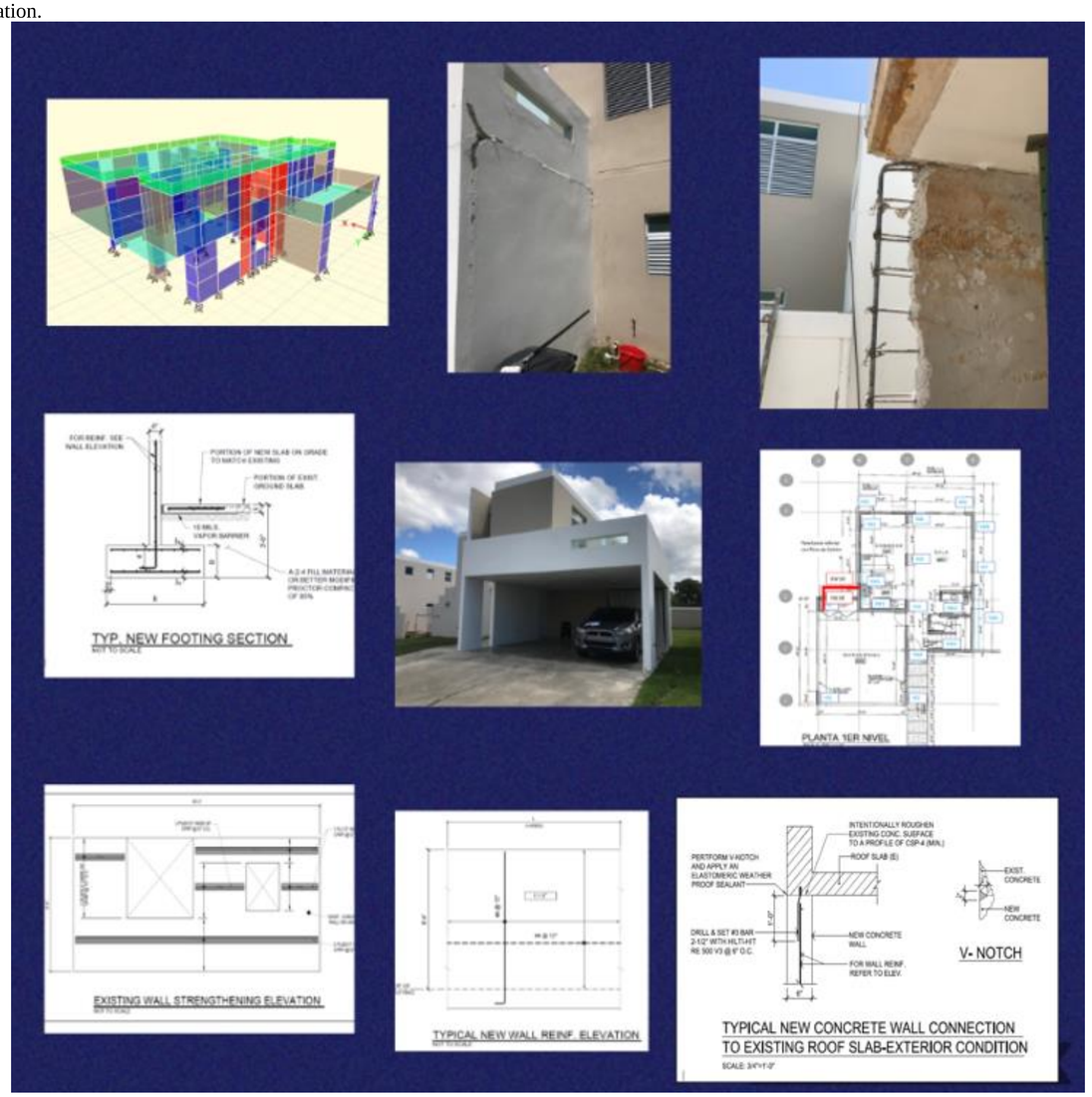
Problem

As a research conclusion, it is important foreground that the studied structure is not aligned with requirement of the capacity design, actual codes requirements. These actual codes are more restrictive than the originally used on the design. Consequently, the seismic capacity and basal shear stress have an incremental design values for more 30 % compared with the one used for this design. In addition, of the construction issues deficiencies impact increment the possibility of structure fails.
As a result, a rehabilitation procedure shall be taking in consideration to provide and improve the capacity of the deficient elements and sections.

Methodology

Its research are based into two phases for a proper investigation. Phase I – An evaluation of the structure using the currents design drawings conditions evaluated with the codes correspondent to the design completion date. Was evaluated using an Static Analysis and Respond Spectra or Modal Analysis. Phase II - An evaluation of the structure as constructed, including construction issues findings, but using the actual codes using for structural analysis. It was evaluated using an Dynamic Modal Analysis to determine the magnitude of Shear. On both methods was evaluated and calculated seismic demand, structural steel reinforcement capacity, shear capacity, displacement and drift.
Moreover, an integrated software (ETABS) were utilized for the structural analysis evaluation, considering all the parameters, evaluation, sections, materials from the drawings and the geographic location. .
The overall structure was divided in multiple smaller sections and a data base was created to obtain the information required for evaluation.

Figura 6



Results and Discussion

Consequence of results obtained in this research the evaluation of each phase (I and II) and their results were comparable each with the other, satisfied the initial fail hypothesis. Both phases, showed an important deficiency of structural steel reinforcement elements, considered from the origin of design and becoming more critical with the use of application of the most resents designs codes. That deficiency of steel reinforcement contribute into structure fail. Consequently, the shear capacity evaluation of some elements indicated with calculation of capacity/demand ratio that the structure can be affected by external conditions. Accordingly, values over 1.0, predicting the probability of fails of these components. Others parameters were evaluated, but didn't show any effect to the structure fails. Structure displacement, drift and basal shear was calculated and compared with the allowable values, concluding the no contribution of structure responds.

Conclusions

After the research analysis, important conclusion needs to be considered. After the fact, the structure under investigation was structurally affected due construction deficiencies anchorage system and deficiencies in the structural steel reinforcement not considered in the base of the design. Shall be necessary rehabilitate the structure considering the actual codes and retrofit the construction deficiencies.
As part of the rehabilitation systems, it was necessary to make a combination of several techniques in order to reach the final compliance solution. It considers at first stage the restoration of all cracked elements in the structure, using injections with high-viscosity epoxy products to restore the integrity and rigidity affected. It solution will provide an immediate improvement giving them back an optimal condition reestablishing the capacity to transfer load as expected. Moreover, rehabilitation of cracks, it will be necessary to demolish and replace several affected elements, such walls and foundations and rebuilding with new engineering details and a substitution of materials (CMU to Concrete). In addition, use an applicable carbon fiber products, for a wall section, to provide them the reinforcement and capacity required.

Future Work

Consequently to this research shall be necessary evaluate others minor structures fails impacted by the earthquake event. Condition similar to Short Column effect, Concrete Masonry Units integrity and evaluation of Non Regular structures.

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References

[1] Uniform Building Code, 1997.
[2] Minimum Design Loads and Associated Criteria for Buildings and Others Structures, ASCE 7-16, 2017.
[3] Building Code Requirements for Structural Concrete and Complementary, ACI-318-14, 2017.
[4] Seismic Evaluation and Retrofit of Existing Buildings, ASCE 41-17, 2017.